

WHAT IS CLAIMED IS:

1. A laser for generating ultra-short optical pulses, comprising:
a cavity which repeatedly passes light energy along a cavity axis;
a length of multi-mode optical fiber doped with a gain medium and positioned along
said cavity axis;
a pump for exciting said gain medium;
a mode locking mechanism positioned on said cavity axis; and
an optical guide positioned on said cavity axis which confines the light
amplified by said multi-mode optical fiber to preferentially the fundamental mode of
said multi-mode optical fiber.
2. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein
said mode locking mechanism comprises a passive mode locking element.
3. A laser for generating ultra-short optical pulses as defined in Claim 2 wherein
said passive mode locking element comprises a saturable absorber.
4. A laser for generating ultra-short optical pulses as defined in Claim 3 wherein
said saturable absorber comprises InGaAsP.
5. A laser for generating ultra-short optical pulses as defined in Claim 3
additionally comprising a power limiter for protecting said saturable absorber.
6. A laser for generating ultra-short optical pulses as defined in Claim 5
wherein said power limiter comprises a two photon absorber.
7. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein
said optical guide comprises a single-mode mode-filter fiber on said cavity axis.
8. A laser for generating ultra-short optical pulses as defined in Claim 7 wherein
said single-mode mode-filter fiber is fusion spliced onto one end of said multi-mode optical
fiber.
9. A laser for generating ultra-short optical pulses as defined in Claim 8 wherein
said multi-mode fiber is tapered at said fusion splice.
10. A laser for generating ultra-short optical pulses as defined in Claim 8 wherein
said single-mode mode-filter fiber is tapered at said fusion splice.
11. A laser for generating ultra-short optical pulses as defined in Claim 8 wherein
both said single-mode mode-filter fiber and said multi-mode fiber are tapered at said fusion
splice.
12. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein
said pump is coupled to said multi-mode fiber along said cavity axis.

13. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said pump is coupled to the side of said multi-mode fiber.
14. A laser for generating ultra-short optical pulses as defined in Claim 13 additionally comprising an optical coupler for coupling said pump to said multi-mode fiber.
- 5 15. A laser for generating ultra-short optical pulses as defined in Claim 13 additionally comprising a v-groove on said multi-mode optical fiber for coupling said pump to said multi-mode fiber.
- 10 16. A laser for generating ultra-short optical pulses as defined in Claim 1 additionally comprising a polarization beam splitter for outputting said ultra-short optical pulses from said laser.
17. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said cavity comprises a pair of reflectors at its opposite ends.
- 15 18. A laser for generating ultra-short optical pulses as defined in Claim 17 wherein one of said pair of reflectors is partially reflecting and provides the output for said cavity.
19. A laser for generating ultra-short optical pulses as defined in Claim 17 wherein said mode locking mechanism comprises a saturable absorber, and wherein one of said reflectors is formed on a surface of said saturable absorber.
- 20 20. A laser for generating ultra-short optical pulses as defined in Claim 19 wherein said mode locking mechanism additionally comprises a power limiter for protecting said saturable absorber, and wherein said saturable absorber is formed on a surface of said power limiter opposite said one of said reflectors.
- 25 21. A laser for generating ultra-short optical pulses as defined in Claim 20 wherein said power limiter comprises a two-photon absorber.
22. A laser for generating ultra-short optical pulses as defined in Claim 1 additionally comprising a linear phase drift compensator on said cavity axis.
23. A laser for generating ultra-short optical pulses as defined in Claim 22 wherein said linear phase drift compensator comprises a Faraday rotator.
- 30 24. A laser for generating ultra-short optical pulses as defined in Claim 23 wherein said linear phase drift compensator comprises a pair of Faraday rotators.
25. A laser for generating ultra-short optical pulses as defined in Claim 22 additionally comprising a linear polarization transformer on said cavity axis.
26. A laser for generating ultra-short optical pulses as defined in Claim 25 wherein said linear polarization transformer comprises a wave plate.

27. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said mode locking mechanism comprises an active mode locking element.

28. A laser for generating ultra-short optical pulses as defined in Claim 27 wherein said active mode locking element comprises an optical amplitude modulator.

5 29. A laser for generating ultra-short optical pulses as defined in Claim 27 wherein said active mode locking element comprises an optical frequency modulator.

30. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said ultra-short optical pulses preferentially in the fundamental mode of said multi-mode optical fiber have a pulse width below 500 psec.

10 31. A laser for generating ultra-short optical pulses as defined in Claim 1 additionally comprising an environmental stabilizer on said cavity axis to assure that said cavity remains environmentally stable.

32. A laser for generating ultra-short optical pulses as defined in Claim 31 wherein said environmental stabilizer comprises a Faraday rotator.

15 33. A laser for generating ultra-short optical pulses as defined in Claim 32 wherein said environmental stabilizer comprises a pair of Faraday rotators.

34. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said optical guide comprises an optical fiber doped with an amplifying medium to provide gain guiding.

20 35. A laser for generating ultra-short optical pulses as defined in Claim 34 wherein said amplifying medium is concentrated centrally within a fraction of the core diameter of said optical fiber.

36. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said optical guide comprises a single-mode optical fiber on said cavity axis.

25 37. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said optical guide comprises a mode-filter on said cavity axis.

38. A laser for generating ultra-short optical pulses as defined in Claim 37 wherein said mode filter excites the fundamental mode of said multi-mode fiber.

30 39. A laser for generating ultra-short optical pulses as defined in Claim 38 wherein said mode filter excites the fundamental mode of said multi-mode fiber with an efficiency of at least 90%.

40. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said cavity additionally comprises a positive dispersion element.

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41. A laser for generating ultra-short optical pulses as defined in Claim 40 wherein said positive dispersion element comprises a length of single-mode positive dispersion fiber positioned along said cavity axis.

5 42. A laser for generating ultra-short optical pulses as defined in Claim 41 additionally comprising an output coupler for limiting the light energy at said single-mode positive dispersion fiber to less than 10% of the peak power in said cavity.

43. A laser for generating ultra-short optical pulses as defined in Claim 42 additionally comprising a frequency converter for compressing pulses generated by said cavity.

10 44. A laser for generating ultra-short optical pulses as defined in Claim 43 wherein said frequency converter comprises a frequency doubler.

45. A laser for generating ultra-short optical pulses as defined in Claim 44 wherein said frequency doubler comprises chirped periodically poled LiNbO₃.

15 46. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said multi-mode fiber includes a core, and wherein said gain medium in said multi-mode optical fiber is concentrated centrally within the core of said multi-mode fiber.

47. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said multi-mode optical fiber is polarization-maintaining.

20 48. A laser for generating ultra-short optical pulses as defined in Claim 47 wherein said polarization-maintaining multi-mode fiber has an elliptical core.

49. A laser for generating ultra-short optical pulses as defined in Claim 47 wherein said polarization maintaining multi-mode fiber comprises stress-producing regions.

25 50. A laser for generating ultra-short optical pulses as defined in Claim 1 wherein said cavity additionally comprises a fiber grating written onto said multi-mode fiber, said grating primarily reflecting the fundamental mode of said multi-mode fiber.

30 51. A method of generating ultra-short pulses, comprising:
providing a length of optical fiber doped with a gain medium;
repeatedly passing signal light through said length of optical fiber to produce said ultra-short pulses; and
providing sufficient stored energy within said gain medium to amplify said pulses to a peak power above 1 KW.

52. A method of generating ultra-short pulses as defined in Claim 51 additionally comprising:

environmentally stabilizing said optical fiber.

53. A method of generating ultra-short pulses as defined in Claim 51 additionally comprising mode locking said optical fiber.

54. A method of generating ultra-short pulses as defined in Claim 51 wherein said providing step comprises providing a multi-mode fiber doped with a gain medium.

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(B) 55. A method of generating ultra-short optical pulses, comprising:
circulating light energy within a cavity;
amplifying said light energy within said cavity in a multi-mode fiber; and
confining said light energy within said cavity substantially to the fundamental mode of said multi-mode fiber.

10 ~~52~~ 56. A method of generating ultra-short optical pulses as defined in Claim ~~55~~ 51 additionally comprising mode locking said light energy.

~~53~~ 57. A method of generating ultra-short optical pulses as defined in Claim ~~55~~ 51 wherein said confining comprises mode filtering said light energy.

15 ~~54~~ 58. A mode-locked laser for generating high power ultra-short optical pulses, comprising:

A multi-mode optical fiber doped with gain material for amplifying optical energy;
means for pumping said optical fiber; and
means for confining the optical energy amplified by said multi-mode optical fiber to substantially the fundamental mode of said multi-mode optical fiber.

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